

Proximal Biceps Tendon
A Biomechanical Analysis of the Stability at the Bicipital Groove

Young W. Kwon, M.D., Ph.D., Jason Hurd, M.D., Keith Yeager, B.E., Charbel Ishak, M.D., Peter S. Walker, Ph.D., Sami Khan, M.D., Joseph A. Bosco III, M.D., and Laith M. Jazrawi, M.D.

Abstract
The subscapularis tendon, coracohumeral ligament, and transverse humeral ligament are all believed to contribute to biceps tendon stability within the bicipital groove. In order to examine the relative contribution of these soft tissue structures to proximal biceps tendon stability, 11 fresh frozen cadaveric shoulder specimens were prepared and mounted onto a custom jig. A three-dimensional digitizer was utilized to record biceps tendon excursion in various shoulder positions. In sequential order, these structures were then sectioned, and biceps tendon excursion was again recorded. We found that sectioning of the subscapularis tendon significantly increased biceps tendon excursion, compared to intact specimens (8.1 ± 4.1 mm vs. 4.3 ± 3.6 mm; p < 0.006). In contrast, isolated sectioning of the transverse humeral ligament or the coracohumeral ligament did not significantly increase biceps excursion (5.4 ± 2.5 mm, p = 0.26; 5.6 ± 1.3 mm, p = 0.24). When two structures were sectioned, significant excursion in the biceps tendon only occurred in specimens where the subscapularis tendon was one of the sectioned structures. The preliminary data suggest that, of the three tested soft tissue structures, the subscapularis tendon is the most important stabilizer of the proximal biceps and that clinically significant lesions of the proximal biceps tendon may be associated with a defect in the subscapularis tendon.

After originating from the superior aspect of the glenoid labrum, the proximal biceps tendon exits the glenohumeral joint at the junction between the subscapularis and the supraspinatus tendons in what is commonly referred to as the rotator interval. At this juncture, the tendon lies within the bicipital groove of the humeral head until it emerges on the anterior aspect of the proximal humeral shaft. The tendon is believed to be stabilized within this bicipital groove by the surrounding soft tissue structures. Dislocations as well as acute ruptures of the proximal biceps tendon have clearly been linked to pathological tears of the subscapularis tendon (ST).1-5 Hence, it is recommended that rotator cuff integrity be carefully examined when a patient presents with either a ruptured proximal biceps tendon or with significant pain about the bicipital groove. However, anatomic studies have also demonstrated that the coracohumeral ligament (CHL) forms an anterior band around the proximal biceps tendon and may be its primary stabilizer.6,7 In addition, case reports have suggested that the biceps tendon can dislocate without a tear in the rotator cuff tendons.8,9 Thus, the clinical significance of biceps tendon dislocation on the integrity of the nearby soft tissue stabilizers remains uncertain.

The purpose of this study, therefore, was to examine the relative contributions of various soft tissue structures in maintaining the biceps tendon within the bicipital groove. Specifically, we tested the effects of sectioning the ST, the CHL, and the transverse humeral ligament (THL) on the stability of the proximal biceps tendon. With this analysis, we sought to identify the “key” structural defect that may be associated with a proximal biceps tendon instability.

Materials and Methods

Eleven fresh frozen cadaveric shoulder specimens were obtained from cadavers whose age was less than 60 years. In addition, the specimens were checked to ensure the integrity of the soft tissues. The overlying soft tissues, including the skin and the deltoid muscle, were removed. Position of the forearm was marked on the humerus to identify rotation of the shoulder. The specimen was then transected at the distal humerus and mounted on a custom built jig by placing two screws through the scapula. The ST and the THL were easily identified and isolated. The CHL was first identified at its origin at the base of the coracoid process. It was then followed laterally until its entire insertion was clearly isolated (Fig. 1). After confirming the structural integrity of the soft tissues to be tested, 15 N was applied to the distal biceps tendon through a pulley system that maintained this tension through all shoulder positions. The bicipital groove and the superior portion of the biceps tendon at the upper border of the groove were identified, and their positions were recorded using the Microscribe Digitizer (Immersion Corp., San Jose, California) in a three-dimensional surface modeling program, Rhinoceros (McNeel North America, Seattle, Washington).

The humerus was then elevated to 0°, 30°, 60°, and 90° in the plane of the scapula. The medial border of the scapula established the vertical axis in our system. At each of these angles, the humeral head was placed in 30° internal rotation, neutral, and 30° external rotation. At all these positions, the position of the biceps tendon relative to the bicipital groove was recorded. The ST, CHL, and THL were then sectioned in a sequential manner. The order of the soft tissue sectioning was altered among the specimen in order to test all the sectioning scenarios. For isolated sectioning of the ST and CHL, four specimens each were tested. Three specimens were tested after isolated sectioning of the THL. Similarly, four specimens each were tested for combined sectioning of the ST-CHL and CHL-THL, while three specimens were tested for combined sectioning of the ST-THL. After each sectioning, the position of the biceps tendon relative to the bicipital groove was again recorded at each of the shoulder positions.

After data was collected, all soft tissue about the bicipital groove was removed from the humerus, and the morphology of the bicipital groove was recorded with the Microscribe Digitizer. Using this data, a three-dimensional surface model of the humerus was created in the Rhinoceros program. This model was then joined with the recorded biceps tendon location data. The final model demonstrated the proximal humerus anatomy with an overlay of the biceps tendon location at various shoulder positions (Fig. 2). From this model, total excursion of the biceps tendon relative to the bicipital groove was measured for all specimens before and after sectioning of the soft tissues. All statistical analyses were performed using a paired Student’s t-test in the Sigma Stat program (Systat Software Inc., San Rachel, California). Statistical significance was assigned at p < 0.05.

Results

A summary of the data is presented in Table 1. In the 11 intact specimens, the biceps tendon excursion within the
bicipital groove ranged from 0.8 mm to 9.0 mm, with an average of 4.4 ± 2.5 mm (mean ± standard deviation). Once all three structures were sectioned, the biceps tendon clearly dislocated out of the bicipital groove in all of the specimens. The bicipital groove depths in the specimens were measured to be 4.2 ± 0.8 mm (range, 2.7 mm to 5.4 mm).

After single structure sectioning, the ST lesion was associated with the greatest increase in biceps tendon excursion within the groove. In these four specimens, the tendon excursion increased from 4.3 ± 3.6 mm to 8.1 ± 4.1 mm (p < 0.006). One of these speciment demonstrated a visible dislocation of the tendon from the bicipital groove. This occurred at 0° of elevation and 30° of internal rotation, as well as at 90° of elevation and 30° of external rotation. Once the shoulder was placed back in neutral position (0° of elevation and rotation), however, the biceps tendon returned back into the groove. In general, rotation of the humeral head caused a greater excursion of the tendon than shoulder elevation. With the small sample size, however, it was not possible to clearly characterize this trend. In addition, no single position reproducibly demonstrated the greatest excursion of the biceps tendon in comparison to neutral position.

In contrast, isolated sectioning of the CHL and the THL resulted in biceps tendon excursions of 5.4 ± 2.5 mm and 5.6 ± 1.3 mm, respectively. Neither of these increases was found to be significant. In fact, with the exception of one THL sectioned specimen whose bicipital groove was the most shallow at 2.7 mm, none of these specimens demonstrated bicipital tendon excursion that could be visually appreciated.

After sectioning of two structures, any lesion associated with an ST defect resulted in a significant increase in biceps tendon excursion. Thus, specimens with ST-CHL and ST-THL lesions demonstrated biceps tendon excursions of 7.1 ± 3.0 mm and 10.4 ± 4.0 mm, respectively, and both of these increases were statistically significant in comparison to intact specimens (p < 0.038 and p < 0.029, respectively). Biceps tendon excursion in specimens with the combined lesions of CHL-THL did increase to 6.7 ± 1.5 mm, but this was not found to be statistically significant. In addition, biceps tendon excursion in the CHL-THL scenario was greatest in the specimen with the shallow bicipital groove, as mentioned above. If data from this specimen is eliminated, the difference in average biceps tendon excursion before and after CHL-THL lesions was only 0.9 mm. Finally, as mentioned above, one of the specimens with ST sectioning demonstrated a frank dislocation of the biceps tendon from the bicipital groove at certain positions.

### Discussion

A previous study suggested that the CHL is the primary stabilizer of the proximal biceps tendon and that sectioning of this structure will lead to medial dislocation of the biceps tendon.7 Similarly, O’Donoghue reported subluxations and dislocations in 56 throwing athletes without rotator cuff tears.8 In addition, a recent case report presented a patient with intact ST, whose proximal biceps tendon was medially dislocated.8 In our experiments, however, the ST was clearly the most important stabilizer of the tendon, and isolated sectioning of the CHL or the THL produced only minimal excursion of the tendon within the bicipital groove. In addition, with a single exception as mentioned above, unless all three structures were sectioned, a frank dislocation was never observed in our specimen. The discrepancy between our data and the previous studies cannot be clearly explained.

Recently, Gleason and colleagues demonstrated in a laboratory study that the THL may not be a separate anatomic entity. Rather, they suggested that the THL is actually a sling-like structure formed by the superficial fibers of the ST.1 Regardless of the nomenclature, in our study, the THL specifies the ligamentous structure directly overlying the bicipital groove (Fig. 1). Isolated sectioning of this structure was not associated with significantly increased excursion of the biceps tendon. The ST sectioned in this study included the deep fibers of the tendon that attached onto the superior portion of the lesser tuberosity.6 Similarly, Jost and coworkers demonstrated that the lateral aspect of the rotator interval consisted of four separate layers and that the CHL had a broad insertion in multiple layers into both the greater and the lesser tuberosities.6

In addition, the investigators described that the ligament formed an anterior band around the biceps tendon at the most proximal aspect of the lesser tuberosity. In our ex-

### Table 1  Biceps Tendon Excursion Before and After Soft Tissue Sectioning

<table>
<thead>
<tr>
<th>Sectioned Structures</th>
<th>Biceps Tendon Excursion Before Sectioning (Mean ± Standard Deviation)</th>
<th>Biceps Tendon Excursion After Sectioning (Mean ± Standard Deviation)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>ST</td>
<td>4.3 ± 3.6 mm</td>
<td>8.1 ± 4.1 mm</td>
<td>0.006</td>
</tr>
<tr>
<td>CHL</td>
<td>4.7 ± 2.5 mm</td>
<td>5.4 ± 2.5 mm</td>
<td>0.255</td>
</tr>
<tr>
<td>THL</td>
<td>4.3 ± 1.7 mm</td>
<td>5.6 ± 1.3 mm</td>
<td>0.243</td>
</tr>
<tr>
<td>ST-CHL</td>
<td>3.4 ± 1.4 mm</td>
<td>7.1 ± 3.0 mm</td>
<td>0.038</td>
</tr>
<tr>
<td>ST-THL</td>
<td>4.7 ± 4.1 mm</td>
<td>10.4 ± 4.0 mm</td>
<td>0.029</td>
</tr>
<tr>
<td>CHL-THL</td>
<td>5.3 ± 2.3 mm</td>
<td>6.7 ± 1.5 mm</td>
<td>0.081</td>
</tr>
</tbody>
</table>

ST, Subscapularis tendon; CHL, Coraco-humeral ligament; THL, Transverse humeral ligament.
periments, the CHL was first isolated from its origin and followed laterally. The entire insertion of the ligament was then severed from the bone. Hence, it is likely that both the deep and the superficial portions of the ligament insertion were sectioned. An isolated sectioning of this structure did not significantly increase the excursion of the biceps tendon in our experiments.

One of the limitations of this study was not testing the contribution of the anterior edge of the supraspinatus tendon to proximal biceps stability. Anatomic as well as clinical observations suggest that this portion of the tendon may contribute to the stability of the biceps tendon. Hence, future studies will test this hypothesis. Another limitation of the study is the static nature of the measurements. Dynamic measurements of the excursion may have resulted in additional information regarding the specific patterns of biceps movement relative to shoulder position and soft tissue lesions. Finally, the anatomic nature of this study prevents a clear association of increased biceps tendon excursion to the clinically relevant proximal biceps tendon lesion, whether it be instability or a structural damage.

Despite these limitations, however, these data provide useful information regarding proximal biceps lesions and associated pathology. Of the three tested soft tissue structures, the ST was clearly the most important stabilizer. Even with defects in the CHL or THL, the proximal biceps tendon remained fairly stable if the ST was intact. Walch and associates described articular sided tears of the superior lateral ST and coined the term “hidden lesion,” because it is not visible during an open anterior operative approach to the shoulder. This disruption of the superior lateral portion of the ST is typically associated with medial subluxation and instability of the proximal biceps tendon. Likewise, Weishaupt and colleagues demonstrated that, among the patients with documented biceps tendon “pulley lesion,” the most consistent finding on an MR (magnetic resonance) arthrogram was a signal abnormality on the superior border of the ST insertion. Our preliminary data support these clinical observations that disruption of the ST is the most important factor leading to the proximal biceps tendon instability.

Disclosure Statement
None of the authors have a financial or proprietary interest in the subject matter or materials discussed, including, but not limited to, employment, consultancies, stock ownership, honoraria, and paid expert testimony.

References